SCIENCE

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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SCIENCE AND INVESTMENT[1]

INTRODUCTION

THE influence of science upon the investment of capital and the employment of labor in productive enterprises is far from receiving its due recognition in systematic economics. There is a vague sort of knowledge that science and productive industry are related much as a handmaid is related to a household. One looks in vain, however, in any of the standard treatises on economics for anything like an adequate appreciation of the place of the natural sciences in that all-engrossing and highly standardized process of production and exchange which makes up the modern system of industry known as capitalism.

One reason for this lies in the fact that the line of approach of the professional economist to the existing system has been by way of politics or philosophy—by inexact and speculative methods, rather than by the more exact methods of experiment and verification. The bias of approach has left its mark in the inconclusiveness of economic discussion, in the lack of agreement as to what is settled and what is not, and even in the question as to what the real scope and aims of economics are. Under the term "progress of nations" we include a complex group of forces. When we come to weigh them out one by one, it will appear that the greatest motive force in the

[1] Address of the retiring vice-president of Section I at the Baltimore meeting of the American Association for the Advancement of Science.

unfolding of material power in modern times has been that of the various sciences. In fact, it is this leavening of our western civilization with the knowledge and power of the natural sciences, in their mastery over the forces of nature in the service of man, that, more than any other single criterion, marks off modernity from all that goes before it.

SERVICES OF GEOGRAPHY AND ASTRONOMY

Historically speaking, the earliest of modern sciences to affect the nature and scope of investment was geography. The European explorations and discoveries of the fourteenth and fifteenth centuries added an area of territory to the field of commerce, probably three times the size of that known to western Europe prior to the rounding of Africa, the opening of a sea-route to India, and the discovery of the American continent. Then followed the formation of the great trading corporations, of which the East India Company was typical. These corporations broadened out into the colonial policies of western Europe, in the effort to exploit the lands thus discovered for the enrichment of the home countries. Thus in the short period of a single century the map of the entire world had changed, almost beyond recognition—all because the science of geography had enabled the researchful spirits of those times to pass from the confines of the known out into the unknown.

The next of the sciences to influence the progress of modern investment was astronomy. It was by the aid of the science of the heavenly bodies that ocean navigation was rendered possible. It is not too much to say that the annexation of the oceans to the world's area of free enterprise was, next to the discovery of America, the one thing that had most to do with making modern nations what they are in things material. On this basis of maritime traffic, nine tenths of the world's international trade rests. The sea is as vital to Great Britain, and nearly as vital to the national life of Germany, as food is to the body. And yet, without the contributions of astronomy the commerce of the world, which normally among the nations exceeds $25,000,000,000 a year, would be little more than a coasting trade, whose vessels hug in fear the shores of inland seas and the ocean frontages of their own countries.

These two sciences—geography and astronomy—together put into the hands of man the powers whereby he, within a comparatively short period of time, enlarged the extent of the world's market by three times its earlier area and taught men the art of mastering maritime transportation, thus connecting the world's continents by highways over a field of intercourse covering three fourths of the area of the globe. These sciences, when yet in their infancy, laid the foundations of the commercial, industrial and financial powers whose wealth has since assumed proportions so colossal as to stagger the vividest imagination.

METALLURGY AND THE RÉGIME OF MONEY

The next group of sciences which have radically influenced the course of modern enterprise and investment is that which includes the production and the manufacture of metals. Mining and metallurgy put the old world in possession of the precious metals of the new. The infusion of metallic money in such unheard-of quantities into the economic life of Europe was one of the most revolutionary forces that ever came to any age. There was not a single institution, social relation or business contract that did not undergo radical transformation, by virtue of the effect of the precious metals upon the laborer and the employer, the state and the subject, the debtor and the creditor. The precious metals put the monetary systems of the na-

tions on a metallic basis and thus for the first time gave to them a common standard of international value.

Thus far the three distinct contributions of the sciences to the economic factors that go to make up the modern world market are: (1) The discovery of new lands, (2) the utilization of ocean transportation—the cheapest known and (3) an international standard of value. These three things have determined the plane on which investment activity in its most comprehensive scope is still working out its various problems under the guidance and direction of the sciences of geology, chemistry, physics and engineering.

SCIENCES IN SELECTION AND SUBSTITUTION

Possibly the most signal contribution of geology to the advance of investment is seen in the service which national and state surveys render to the development of natural resources. Each of the American commonwealths now regards such an inventory of the earth's formations and composition as geology alone can give as the indispensable condition of inducing capital to seek profitable employment within its borders. Investment of to-day is itself specialized in such a way that it depends upon the specialist's most complete researches to ascertain beforehand the wisdom or the unwisdom of putting capital of any given amount into an enterprise, as well as of locating it with due regard to the assemblage of the materials of production and to the expenses of marketing the products. Geological data determine in large part the answer to these questions. The state survey of the clays of New Jersey decided the location of a large pottery works at the city of Trenton—a point which had ample beds of the chief raw materials, but which also had the advantage of being half way between two cities of over a million population, yet not a hundred miles apart.

Thus the sciences, besides encompassing the globe to determine where nature has hid her treasures, determines where lines of transportation shall be laid down, where population is destined to concentrate, and in what particular channels of employment both labor and capital may find the maximum returns. In other words, science is a function of economic progress, operating under the law of substitution. According to that law, the fall of the rate of profits impels the producer of commodities to find some less expensive substitute among the articles that make up the elements of the cost of production. In the other direction, the making of extraordinary profits may effectively impel the producer to escape the limitation of supplies which keep him from entering on large-scale production, thus multiplying his profits manifold. The burden of discovering what might serve as economical substitutes falls upon the scientific laboratory.

EVOLUTION OF MACHINE INDUSTRY AND TRANSPORTATION

The chemical and physical laboratory constitute the experimental and exploring arm of the up-to-date industry. The railroad must have it to test its materials. The manufacturer must have it to insure himself, not only against deliveries of inferior materials in contract, but even more so to enable him promptly to test the applicability of any new discovery to his business, to decide as to whether or not there is any advantage to him in changing his methods, and to put to test his finished product before it is sent out, thus detecting any defect in construction which actual use might disclose.

Not only has science made industry and commerce more technical, calling progressively for a more highly skilled and a more varied class of labor and talent, but it has without doubt been the chief factor in differentiating modern industry and com-

merce from the handicraft state in the one case and from the primitive forms of transportation on the other. I put it approximately near the truth in saying that machine industry, meaning all work done by mechanical power, would have been impossible but for the use which has been made of physics, chemistry and mechanics in the evolution of the modern system of production and commercial distribution. These three sciences, for instance, share the honor of achievement in the development of the steel rail on our railroads, from the strip of soft iron strung on a pair of parallel girders to a self-sufficient iron rail resting on cross-ties, into the present-day steel rail weighing 100 pounds to the yard. Here we have chemistry, physics, mechanics and metallurgy working conjointly toward an end, which has in turn become the point of departure for a series of developments in the more economical handling of freight. Cutting down costs and increasing carrying capacity have followed the path along which the sciences have led at every stage, in a railway system now representing an investment of $20,000,000,000 in the United States alone.

ENGINEERING AND PUBLIC SERVICE

I need hardly remind you that the most rapid strides among investment activities have indeed been made by those in which science has had the largest sway. These are the fields in which engineering has applied the sciences to profitable uses. One's mind naturally turns to the various enterprises in which electrical power has a domain of its own. Communication, illumination and transportation—three fundamental necessaries of modern living have opened fields of almost unlimited investment possibilities. In all of them, whether it concerns the telephone or the lighting and power problem, the lines of responsible relations with the public are being gradually lain down on safer bases. The popular appreciation of mutual approach to common understanding has already been developed in scores of public service corporations, far beyond the needs of public subscription to capital requirements. The very faith aroused in the soundness of these agencies is an asset of no mean significance in proving the profitableness of their investments.

SCIENTIFIC BASES OF LARGE-SCALE INDUSTRY

It is not usually recognized that science puts a premium on the large-scale industry as compared with the smaller undertaking. The latter can not always afford the expense of maintaining experimental work. The advantage would even be doubtful if it could. But with the consolidation of industries under a central management, the scope of scientific possibilities becomes immensely enlarged. Experiments which demonstrate better results for one plant can immediately be appropriated by all. By the exact measurements of methods and results in one establishment the efficiency of all the others can be tested. This indicates one of the ways in which the sciences have contributed toward the concentration of control and the enormous capitalization of the industrial combinations known as the trusts.

Science in this case pointed out the enormous wastes of so large a number of independent establishments, and helped to measure the extent of economies possible under unified control guided by scientific foresight. We may regret the resulting change. We may even fear for the future of popular welfare in a régime of apparently impregnable combinations. But one thing is sure as fate—and that is this: So far as these consolidations are founded upon scientific bases and remain there, their origin, development and future are assured. But so far as they have had an

artificial and unscientific conception, say in the greed of monopoly, and have vaunted themselves with pride of power unbalanced by the laws of nature, to that extent have they implanted in them the seeds of economic death.

Darwin tells us that for survival two factors are necessary—continuity of type and adaptation to the conditions of existence. Now the work of science in the world's evolution of the type of industry which makes for the maximum general welfare is to increase the degree of adaptability so that the historic type may have the greatest facility of adjustment to actual and prospective needs. Size is the condition of survival. But size uncemented by the scientific spirit, unchartered on the sea of enterprise by the directing captaincy of research, is either doomed to wreck or dry rot. The rise of the corporation, in which form free capital now seeks its widest investment, is the outcome of a search for a type of industrial organization in which the science of the laboratory and the savings of the people may be incorporated under responsible management.

FOUR CRITERIA OF CORPORATE SURVIVAL

This brings me to the point of stating the criteria of survival and development to which the modern business corporation must conform. For I think we all recognize that, although under corporate form, the western world has made unparalleled progress in investment, still the main purposes of investment, namely, personal profit and popular well-being, will not, at this stage of the world's democracy, consent to sacrifice the latter wholly for the former. The corporation will survive only as it serves its function of economic progress, both by being a better producer of wealth out of natural resources and by being a better distributor of wealth, once created, as a product of the unified resources of the community. In short, the corporation as an investment institution gathers into itself the surplus resources of the people, on the at least implied promise of bringing them better returns for its use than they can win working alone. The fulfillment of that obligation, whether regarded as moral or legal, is possible only on condition that it meet to a reasonable degree four distinct criteria of business experience.

Investment within each particular field must no longer hazard the certainty of the outcome on individual management divorced from contact with those who furnished the means necessary to bring labor and capital together under responsible control and cooperation. That business management of entrusted capital may enjoy the certitudes of regular returns it must rest upon scientific, not individual, foundations. Thus will investment of popular savings be lifted out of the boggy ways of speculative risks and be raised to the level of demonstration.

First of all, then, the type of investment institution that will meet modern conditions of existence must be *scientific*, in that it must follow the path of demonstrated safety as marked out by scientific research. Secondly, the management of such an institution must be a *responsible* one, in the sense of being morally and technically aware of its rights, duties and possibilities. Thirdly, under existing scarcity of capital the world over, and with the prevailing degree of dependence upon the comparatively small investor, the type of investment organization which prevails will have to be *popular*. It will have to appeal to the confidence of the people effectively enough to draw from them necessary capital, not only for initial investment, but for subsequent doses for extension and development. Fourthly and finally, it goes without saying, that any investment agency

which popular judgment will not destroy will have to be *profitable*.

JOHN FRANKLIN CROWELL

A PLEA FOR TERRESTRIAL AND COSMICAL PHYSICS[1]

ONCE upon a time, at a certain small dinner-party, the Duke of Wellington, on being urged to express his opinion frankly of the French marshals he had so successfully worsted in battle, pointed out their good qualities in a most free and magnanimous manner, showing wherein each particularly excelled. Whereupon one of the party said: "Well, sir, how was it that with such various great qualifications you licked them all, one after another?" The duke, taken back, paused, then said: "Well, I don't know exactly how it was, but I think if any unexpected circumstance occurred in the midst of a battle which deranged its whole plan, I could perhaps organize another plan more quickly than most of them."

This power of being able to instantly change an established train of thought, or to be receptive to a new set of circumstances and facts, and thus to be capable of immediately setting up a fresh plan of action, was tersely and most suggestively expressed by Maxwell. When writing Herbert Spencer about a subject of controversy in the latter's "First Principles," he said:

> It is seldom that any man who tries to form a system can prevent the system from forming around him, and closing him in before he is forty. Hence the wisdom of putting in some ingredient to prevent crystallization and keep the system in a colloidal condition.

At the Ithaca meeting of the association, two years ago last summer, I prefaced a paper on the San Francisco earthquake by a few remarks calling attention to the disparity of papers pertaining to the physics of the earth and of the universe presented to-day before sections A and B. I stated it was my impression that this had not always been the case. Attend any similar meeting abroad, be it in England, Germany or France, and you are apt to find the names of foremost physicists down for papers on results of research in terrestrial or cosmical physics. These eminent investigators evidently find food for exhilarating thought and stimulating work in the unraveling of the phenomena of seismology, meteorology, geodesy, hydrology, atmospheric electricity, solar physics, terrestrial magnetism, etc. They appear to regard knowledge gained in the laboratory and in the university merely as a means to an end, not an end in themselves.

The chairman of the Section of Mathematics and Physics at the recent meeting of the British Association was the well-known physicist-meteorologist, Dr. W. N. Shaw, director of the London Meteorological Office. Besides making a most suggestive presidential address, he led an interesting discussion on "The Isothermal Layer of the Atmosphere"—a live topic in meteorology to-day. Those taking part in the discussion were: Shaw, Rotch, Dines, Cave, Turner, J. J. Thomson, Walker and others. Several times has it occurred within recent years at that association, that, owing to the number of titles presented, it was necessary to have a subsection on "Cosmical Physics" which I am very glad to note did not apparently meet with the favor of the physicists themselves. Our British colleagues want the cosmical physicists to stay with them and not flock off by themselves, and the present tendency seems, accordingly, to be at the British Association, not to form such a subsection. Indeed, Dr. Shaw, in the address referred to, said:

[1] Presented at the Baltimore meeting of the American Association for the Advancement of Science, at the general interest meeting of the Section on Physics, December 30, 1908.